CHAPTER 10

Saharan Dust Sedimentation in the Western Mediterranean Sea

K. G. Eriksson

ABSTRACT

The seas bordering North Africa receive yearly a varying amount of wind-borne material, which will be incorporated in the bottom sediments. In the Western Mediterranean Sea a sediment core has been collected at a depth of about 2,800 metres between Spain and Algeria and investigated concerning its amount of eolian material. A sequence of distinct layers of such material is described and approximately dated by the C-14 method. Comparatively great amounts of wind-borne material of silt-size have been brought to the investigated area especially during late Middle Würm and early Post Glacial time.

10.1 INTRODUCTION

Wind-borne materials constitute an important part of the marine sediments in the oceans and seas bordering North Africa; locally they may be the main part. Depending on the topography and the main wind directions certain sea areas receive more dust than others. The amount of dust is always highest near the coast and the grain size as well as the quantity is decreasing in a distal direction. During the last 30,000 years the frequency of strong dust storms have varied considerably according to the investigation of some sediment cores from the Western Mediterranean Sea; in this report only the results from one core, called No. 210, is described. This sediment core was collected from the research ship 'Albatross' by the 1947–1948 Swedish Deep-Sea Expedition led by Professor Hans Pettersson (1957). The core site is centrally located in the southern part of the Algiers–Provençal Basin (Figure 10.1).

10.2 RECENT WIND-BORNE MATERIAL

As an introduction to the description of some sediment layers of wind-borne material in the Western Mediterranean Sea a couple of examples of such dust found in Europe and originating from North Africa will be briefly described.

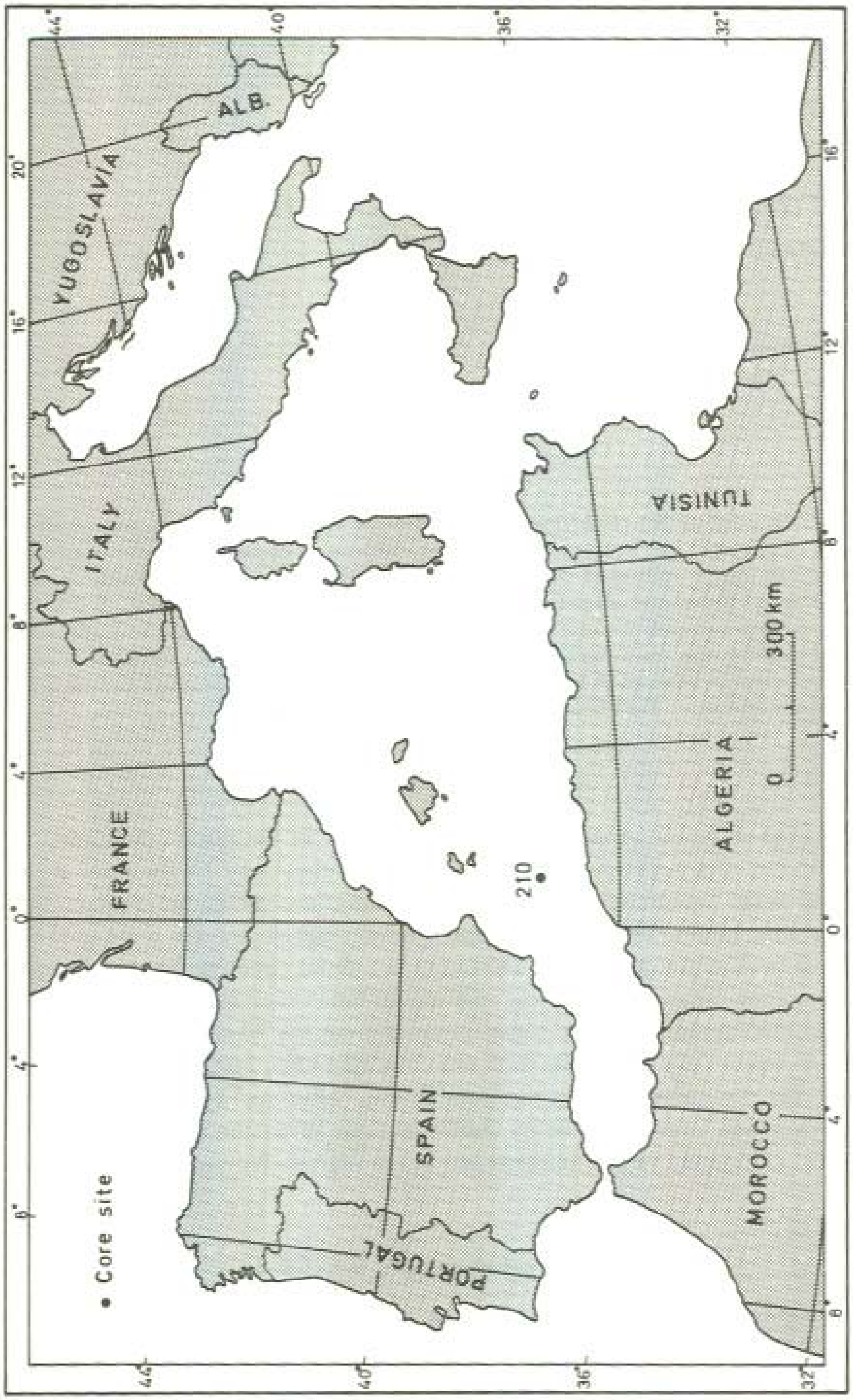


Figure 10.1 Western Mediterranean Sea and the location of Core No. 210

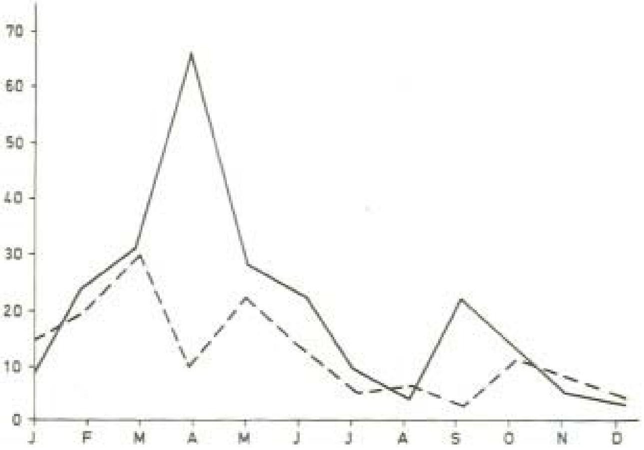


Figure 10.2 ——— Number of sand storms in the Sahara in 1936

---- Number of dust falls in Europe in 1936

(after Glawion, 1939)

Studies of modern sand dunes show that there is a definite relationship between the direction of dune migration and the general atmospheric circulation (Dubief, 1963; Opdyke, 1961). In the Sahara Desert the dunes are moving predominantly southwest and parallel to the trade winds. In the Mediterranean area, on the other hand, the dune fields are moving mainly eastwards because there the westerlies are the dominant winds. Those two facts plus the fact that the Western Mediterranean Sea is surrounded by high mountain ranges suggest that the major part of the sand-sized material transported to the sea by wind is derived from these mountain areas or the coastal regions (North Africa, Spain and France) and not from the Sahara Desert, However, during almost the entire year, especially in autumn and spring when there are changes between the winter and summer atmospheric circulation, there are many sand storms in the Sahara and North Africa. At times these sand storms transport the finest material, the dust, northward over the Mediterranean Sea, (Figure 10.2). Also, on rare occasions, winds are so extraordinarily strong and persistent that dust from the Sahara can be transported as far north as Scandinavia.

Investigations of many of the great dust storms in central Europe during this century have shown that the mineral assemblage of the dust arriving from North Africa and the Sahara Desert is fairly uniform (Thoulet, 1908; Radczewski, 1937; 1939; Gaubert, 1937). As early as 1901, Hellman and Meinardus showed that the principal mineral in the Sahara dust was quartz, many of the grains being well-rounded, frosted, and covered with a film of limonite, with subordinate amounts of mica, calcite, felspars, and limonite. The accessory minerals were usually gypsum, hornblende, tourmaline, garnet, magnetite, epidote, titanite, rutile, and zircon. None of the samples examined at that occasion contained volcanic glass, but many samples contained abundant plant remains and diatoms, the latter of marine as well as of fresh water origin. The grain size of the material investigated ranged between 0.002–0.007 mm.

Götz (1936, p. 227) described an important dust fall over Arosa in Switzerland in 1936. This dust consisted mainly of calcite fragments with subordinate amounts of mica, chalcedony and quartz and most of the particles were covered by limonite. The grain size ranged between <1 and 100 μm; 5 μm was the median grain size.

Stumper and Willems (1947) have examined the great dust fall of March 29th, 1947, at Luxembourg in which the material < 8 μm (33%) consisted mainly of quartz (39%) and plant remains. The mean calcium carbonate content was 9% and the limonite content 9.5%. An approximately similar composition of the same dust deposit was found in Marseille.

Wind-blown dust, probably derived from the Spanish Sahara, collected on a ship in 1962 west of the Canary Islands has been described by Game (1964). This dust consisted mainly of 'aggregate' particles (mostly quartz, mica and clay minerals, determined by X-ray), calcite and rounded to semi-rounded, uncoated quartz grains. More than 80 per cent of the dust particles were between 5 and 30 μm in size.

These and other mineralogical investigations of the modern dust from North Africa and the Sahara Desert show that its principal component is quartz, part of which is rounded and frosted and sometimes coated by a thin film of iron oxide (Eriksson, 1961). Next in abundance is calcite or mica, then plant remains and then accessory heavy minerals, but volcanic glass is unrecorded. The most fine-grained dust usually is reddish and the coarse-grained dust yellowish (Radczewski, 1939; p. 497). Grain-size analyses of dust particles collected on ships off the West African coast show that the particles generally are less than 15 μm in diameter (Radczewski, 1939; p. 498), whereas the median values of particles collected in central Europe are usually smaller.

The dune and sand fields on the coastal areas of the Western Mediterranean Sea are fairly limited in size today, but during the stages of lower sea level they were more extensive. Quartz is usually the dominating mineral. In Late Pleistocene and recent sand dunes near Bone in Tunisia the quartz content is 60–80% followed by calcium carbonates, micas, felspars and heavy minerals (Moussu and Moussu, 1952). Locally in Tunisia, however, some beds of sand-sized material consists mainly of calcium carbonate fragments and it is called calcareous sand (Castany, 1952, p. 83; Norin, 1958, p. 95).

10.3 MICROSTRATIFIED SEDIMENTS

Three types of microstratified sediment have been observed in core 210. Only one type is of importance and this is designated 'microstratified wind-borne material' (Eriksson, 1965).

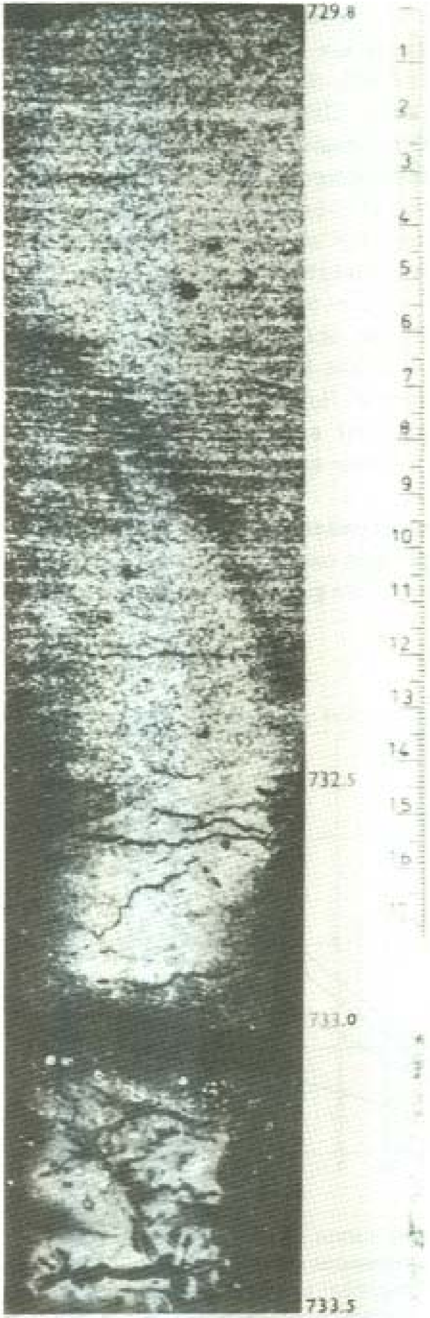


Figure 10.3 Microstratified windborne material. Thin section 733.5–729.8 cm in Core No. 210 (10 times)

To the naked eye the most conspicuous feature of the principal type of micro-stratified sediment is the thinly and regularly laminated structure in which coarse silt alternates with silty clay, in the form of laminations, a fraction of a mm to a few mm in thickness. This is repeated through sequences, up to 1/2 m in thickness, with remarkable regularity. The sediments are classified as marly, clayey silt or silt, usually highly micaceous. This type constitutes about 12% (107 cm) of the core and is observed in 7 beds, having an average thickness of 15 cm; a less well-developed lamination has also been noticed in a few small sections of the ordinary heterogeneous sediments. A bluish-grey shade dominates in the beds of a Würmian age, while yellow-grey predominates in the Postglacial sediments.

In the bed 733–723 cm about 200 laminae were observed in a sediment thickness of 7 cm and in the bed 590–541 cm the same thickness contained between 10 and 100 laminae. However, in the bed examined only the main part is laminated and other parts are non-stratified. No signs of erosion were observed within the beds, but the base usually corresponds to a surface of discontinuity (Figure 10.3).

The amount of silt-sized material averages 70 per cent, clay-sized about 29 per cent and sand-sized 1 per cent only. The low sand-content is noteworthy in view of the high precentage of silt. Two grain-size curves of this sediment type are shown in Figure 10.4.

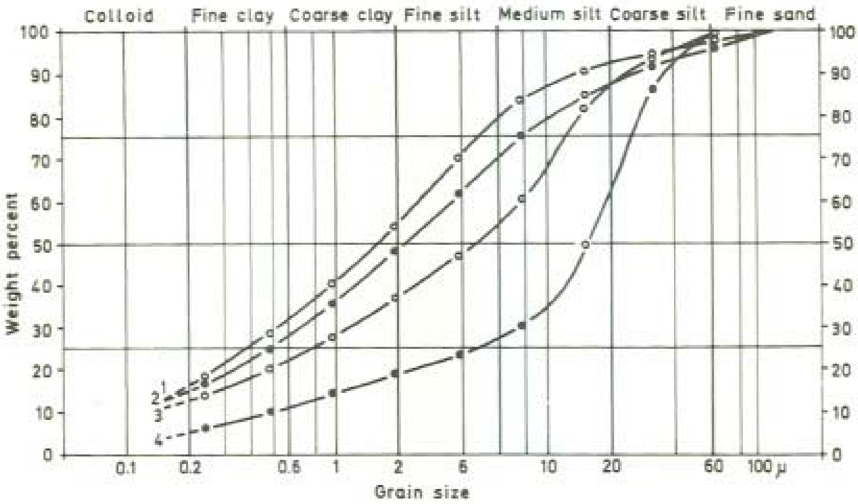


Figure 10.4 Cumulative curves of sediments from Core No. 210

(1) Ordinary, homogeneous sediment; mean of 77 pipette analyses.
(2) Ordinary, heterogeneous sediment; mean of 22 pipette analyses
(3) Microstratified wind-borne sediment; mean of 8 pipette analyses from bed 312.0–284.0 cm.
(4) Microstratified wind-borne sediment; sample 309.5 cm

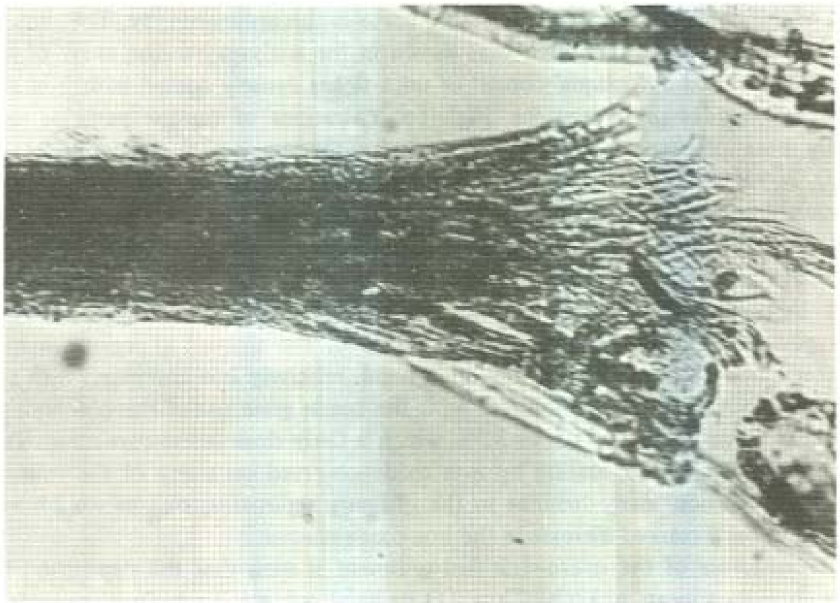


Figure 10.5 Plant fragment which occurs with 'coaly rods' (120 times)

A very conspicuous feature of the microstratified beds at 814.5, 733.0, 331.0, 312.0 and 7.5 cm is the very high content of minute mica flakes, probably mainly sericite, deposited parallel to the plane of sedimentation, sometimes giving the sediment an almost 'shaly' appearance; these beds are also characterized by a high content of 'coaly rods', which has been interpreted as being the ash of burnt grass (Figure 10.5). Fragments of volcanic glass are more frequent in these beds than in the other sediments. The fact that volcanic glass and 'coaly rods' are deposited together is considered as evidence of their continental, wind-borne origin.

Although a similar microstratified structure is exhibited in the beds 590 and 65.5 cm, the content of mica is nevertheless low and 'coaly rods' do not occur. The peculiar microstratification is therefore a feature independent of these components.

The component which predominates in the micro-stratified beds is carbonate which attains a relatively high level in spite of the low content of foraminiferal tests. The mean value, calculated from 64 analyses, is 40%, due mainly to the presence of a large amount of microcrystalline calcite. In the fraction $> 31\ \mu m$ the content of terrigenous minerals, organic detritus, opaque particles and fragments of siliceous organisms has increased relatively to that of the ordinary sediments.

The principal non-calcareous component in the terrigenous assemblage is quartz, which, however, occurs at a lower percentage than in the ordinary sediments. In the heavy mineral assemblage the amphibole/pyroxene minerals are the most abundant (average amount: 0.3 v %). Next in order comes garnet, tourmaline and zircon.

Most of the sanidines observed in core 210 occur in this sediment type. The content of micas is actually higher than that shown in the analyses because many of the particles classified as 'opaque' consist of mica flakes densely coated with iron and manganese oxides or hydroxides. High concentrations of opaque particles have mostly been observed in the micro-stratified sediments, e.g. at the levels 811.0, 730.0, 309.0, 305.5, and 4.5 cm. Moreover, studies of thin sections of the above mentioned mica-rich beds, revealed that the amount of opaque particles seems to be more abundant here than elsewhere in the core, a feature not observed in any other sediment type in the core.

In these sediments are also found the largest amounts of organic detritus (average value: 11 v %) ever measured in core 210. The amount *of organic matter*, as determined chemically is, on the other hand, relatively low compared with the core-mean, which is partly associated with the coarse grain size of this component. The mean value of Fe_2O_3 attains 3.5%, which is fairly close to the core-mean. This is probably due to the coating by iron oxide observed on many of the mineral grains. In addition many laminae in the ordinary sediments, rich in wind-borne material, show a marked increase in the iron-oxide content.

The structure of the micro-stratified sediment is such that the deposition by water currents appears unlikely. Thus, (1) its basal contact is a fairly sharp surface of discontinuity lacking conspicuous signs of erosion; (2) the structure is one of alternating, but indistinctly delimited, very thin laminae, many of which contain 'coaly rods' and volcanic glass, and is therefore atypical of current-deposited sediments in core 210; (3) almost all elongated or flat particles are oriented parallel to the plane of sedimentation which suggests that calm water conditions obtained during deposition. In view of the rather uniform grain-size and the high content of 'coaly rods' the present author has interpreted this structure as arising from a more or less rhythmic supply of wind-borne material. The mineral assemblage with its high content of microcrystalline calcite is suggestive of a wind-borne material of loessic character.

10.4 PERIODS OF HEAVY DEPOSITION OF WIND-BORNE MATERIAL

The dust-material is derived from three principal regions adjacent to the Western Mediterranean Sea, (1) the Sahara Desert, which seems to be the most common source of dust today, (2) the 'tablelands' in Spain, Morocco and Algeria, and (3) the coastal areas, which during the glacial periods were more extensive than today. The investigation gives no reliable evidences of the provenance of the dust material in the microstratified sediments. The relatively low content of microfossils and high amount of 'desert sand' indicate, however, that the source area is a desert or a semidesert.

The time-periods mentioned below are based on dating of selected beds in the core by the ^{14}C method calcareous microfossils $> 44\ \mu m$ (Olsson, 1959; Olsson, 1960; Olsson *et al.*, 1961; Olsson and Blake, 1961–1962; Olsson and Kilicci, 1964; Olsson and Eriksson, 1965). The datings are compared with changes in the number of the most temperature-sensitive species of the foraminiferal assemblages and with other features of stratigraphic importance. Of many reasons it has not been possible to date the different beds with microstratified wind-borne material, and their age has therefore been extrapolated from datings of suitable layers below and above (Figure 10.6).

In the sediment core 210 appears a few periods when the deposition of wind-borne material has been more pronounced than normally.

10.4.1 Würm

The oldest micro-stratified bed in core 210 (814.5–809.0 cm) is rich in micas, 'desert quartz' and volcanic glass. This bed was probably deposited during an early part of the Paudorf–Arcy Interstadial; it might also represent an oscillation caused by an ice advance in the Loess récent II sequence according to Bonifay (1962).

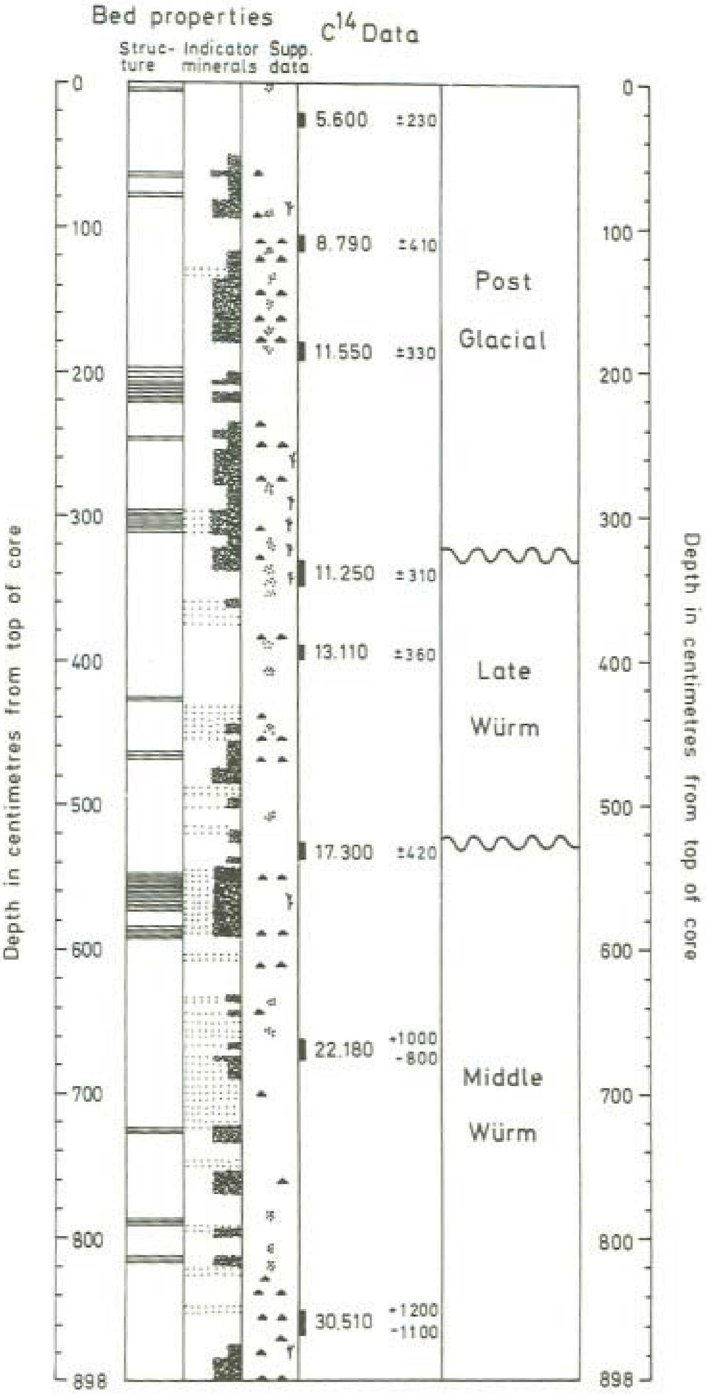
The second micro-stratified bed of mainly wind-borne material is 10 cm thick (733.0 to 723.0 cm). This bed is also rich in mica and, in addition, it has the largest amount of 'coaly rods' and volcanic glass found in core 210.

The chronological position of this bed is uncertain due to the lack of ^{14}C dating; an extrapolation from a dating made on level 670 cm gives a value with a magnitude between 24,000 and 25,000 years corresponding to an early part of the Würm III (Brandenburg ice advance), i.e. the deposition of the oldest sediments of Loess récent III. During this substage of severe cold and rather dry climatic conditions, a steppe-vegetation on loess and sand deposits is known to have existed in Europe as well as in North Africa (Quézel, 1963).

The core-section, 675.0–663.0 cm, has been dated by the ^{14}C method. The resulting age coincides with the Frankfurt ice advance. An extrapolation based on this dating suggests that these sediments were deposited approximately between 24.000 and 18.000 years ago. This very cold and fairly dry substage of the Middle Würm is considered as being a principal time for loess deposition in central Europe, and it is therefore somewhat surprising that the content of loess is not more prominent in this part of core.

Next follows the thickest (49 cm) microstratified bed in core 210, 590.0–541.0 cm. This bed contains no 'coaly rods' and the amounts of organic detritus and volcanic glass are comparatively moderate; the terrigenous mineral assemblage is dominated by micas, chiefly biotite; quartz and heavy minerals are rather common. The sediment is considered to be loessic in character. Due to a low amount of foraminiferal tests this bed has not been ^{14}C-dated, but according to an extrapolation from the dated level 347–337 cm the bed may have been deposited about 18,000 years ago, or during the later part of the maximum extent of Würm III ice advance. During this time of cold and dry climate, the Loess récent III was deposited in southern France. The extension of bed 590.0–541 cm is tentatively correlated with the extensive deposition of loess which took place during the later part of the Würm glaciation (Gross, 1962/63, p. 62).

WESTERN MEDITERRANEAN SEA, Core 210



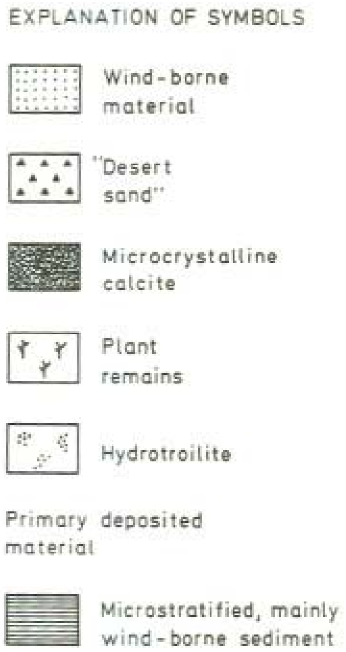


Figure 10.6 Stratigraphy and approximative chronology of the most conspicuous beds of wind-borne material in Core No. 210

10.4.2 Late Würm

During Late Würm or from about 17,000 to 10,000 years ago the deposition of dust in the Algiers–Provençal Basin seems to have been comparatively limited. Only one microstratified bed in the Late Würm period is recognised in core 210 namely the one between 331.0 and 326.0 cm. The sediment is rich in micas and 'coaly rods'. According to an extrapolated dating, this bed was probably deposited during Younger Dryas (11,000–10,000 B.P.). This proposal seems plausible since at that time the deposition of Loess récent IV in southern France continued and in the Sahara the arid climate of Steppe time still persisted.

10.4.3 Post-Glacial

Above a surface of erosion at 312.0 cm there is a bed of microstratified material, 28 cm thick (Figure 10.7). It consists mainly of microcrystalline calcite and calcareous particles of silt-size (mean carbonate content = 45%) and the predominant terrigenous components are quartz, micas, organic detritus including

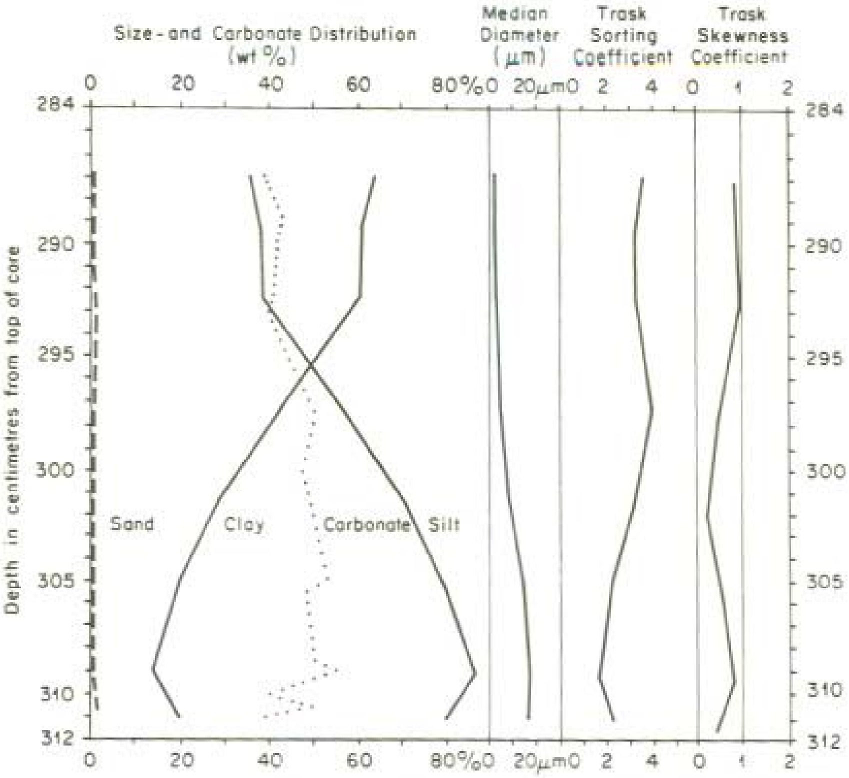


Figure 10.7 Diagram of the grain size and carbonate content distribution in the division 312.0–284.0 cm. The sediment is rich in wind-borne material

'coaly rods' and opaque particles. This bed is probably deposited in the very beginning of the Post-glacial time.

A 5 cm thick microstratified sediment bed (65.5 to 60.0 cm) is deposited around 6,000 years ago or in the beginning of Late Atlantic time. This bed is also rich in calcite grains of silt-size together with quartz and micas; volcanic glass is also present as well as a fair abundance of organic detritus.

10.5 CONCLUSION

This investigation is too limited to allow tenable conclusions concerning the variations in supply of wind-borne material to the Western Mediterranean Sea. It seems, however, rather clear that the periods of transition from one climatic period to another have been extremely stormy bringing comparatively very great amounts of relatively coarse-grained wind-borne material to the investigated area.

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